Theory of Computer Games

電腦對局理論

Tsan-sheng Hsu

徐讚昇

tshsu@iis.sinica.edu.tw

http://www.iis.sinica.edu.tw/~tshsu
Goal

- **Course name:** Theory of Computer Games
  - 電腦對局理論
- **Prerequisite:** Computer Programming, and Data Structure and Algorithms.
- **Goal:** This course introduces techniques for computers to play various games which include Chinese chess and Go.
- **Disclaimers:**
  - NOT yet a course on game theory.
  - NOT yet a course on video games.
  - NOT yet a course on war game simulations.
- **Web page:**
About this course

- **Time and Place:** Every Thursday from 2:20pm to 5:20pm at Room 310 (NTU CSIE building).
  - Sep 18 25
  - Oct 2 9 16 23 30
  - Nov 6 13 20 27
  - Dec 4 11 18 25
  - Jan 1 8 22

- **Dates:**
  - Nov 6 13 20 27
  - Dec 4 11 18 25
  - Jan 1 8 22

- **Format:**
  - Lectures.
  - Presentations for homework projects.
  - Invited lectures.
    - Chinese chess
    - Go
    - . . .
  - Student presentation: the last few lectures if time allows.

- **Class materials**
  - Class notes.
  - Collection of papers.
Acknowledgements

- Thanks to the students of this course for providing constructive feedbacks on the slides.
- Special thanks the following persons.
  - Yuh-Jie Chen (class of 2008)
  - Jennya Chang (class of 2011)
  - Jessica Lin (class of 2011)
  - 許祐程 (TA of the 2012 class)
Evaluation (1/3)

- **Homework (30%)**
  - One homework project about single-agent search (15%)
    - About single agent search.
    - Pick your own game, implement, and then present the result.
  - One homework project about Monte-Carlo simulation (15%)
    - About 2 player games.
    - Your program against TA’s program.

- **Written exam: midterm exam (30%)**
Evaluation (2/3)

- **Final project (40%)**
  - A computer game program for Chinese Dark Chess.
    - A sample code with GUI will be provided.
    - The usage of this sample code is restricted for anything related to this course only.
  - The 8th NTU-TCG Cup.
  - Submitted package: Code + documents.

- **Class participation (bonus)**
Evaluation (3/3)

- Presentation/Report of a research paper on game tree search.
  - If we have more than 16 students, then
    - Bonus for selected students who are obviously falling behind.
  - If we have less than 17 students, then
    - This is required for each student.
    - This will be 10% of your score in which case the two programming homework each take 10%.
  - If time allows, give an in-class presentation.
    - Discussion before presentation.
    - 30-minute talk.
    - \( \leq 30 \) slides in PDF format.
    - 10–15 minutes of Q & A.
    - Each student asks \( \geq 1 \) non-trivial question.
    - Submit your revised set of slides one week later.
  - If time does not allow, a written report.
    - Pick a paper related to the course.
    - Write a report with at least 1000 words in PDF format.
    - Summary of results in the paper.
    - Comments about this paper, its strength, weakness and potential improvements.
Lecturing format

- For each topic
  - The first and most influential papers are introduced.
  - A list of recent and latest papers is provided for further readings and/or topics for presentations.
Topics

- Introduction: an A.I. oriented overview
- Single-player games
- Two-player perfect information games
- Practical considerations
  - Memorizing knowledge
    - *Transposition tables*
    - *Endgame databases*
  - The graph-history interaction (GHI) problem
  - Opponent model
  - Timing control
  - Hardware enhancements
Introduction and an A.I. oriented overview

- Relations between computer games and Artificial Intelligence.
  - Why we study computer games?
  - Why we play or study games?

- History [SvdH02] [Sha50]
  - The Turk, a chess playing “machine” at 1780’s
  - The endgame playing machine at 1910’s
  - C. E. Shannon (1950) and A. Samuel (1960)

- Games that machines have beaten human champions [SvdH02] [Sch00]
  - Chess
  - Othello
  - Checker
  - …
Single-player games

- Games that can be played by one person
  - combinatorial games such as 15-puzzle or Sukodu
  - other solitaire

- Classical approaches [Kor85] [KF02] [CS98]
  - Brute-force, BFS, DFS and its variations including DFID
  - Bi-directional search
  - A*
  - IDA*
  - IDA* with databases

- Disk-based approach [KS05]
Two-player perfect information games (1/2)

- A survey of current status [vdHUvR02]
- Classical approaches
  - Alpha-beta search and its analysis [KM75]
  - Scout and Negascout [Pea80] [Rei83] [Fis83]
  - MTD(\(f\)): Best-first fixed-depth search [PSPdB96] [Pea80] if time allowed
- Enhancements to the classical approaches
  - Aspiration search
  - Quiescence search [Bea90]
  - Move ordering and other techniques [Sch89] [AN77] [Hsu91]
  - Further pruning techniques [SP96] including null move pruning and late move reduction
  - Proof-number search [AvdMvdH94] if time allowed
- Parallel alpha-beta based game tree search [Bro96] [FMM94] [HM02] [HSN89] [Hya97] [Man01]
Monte-Carlo game tree search
- Original ideas [Bru93]
- Best first game tree growing
- UCT
- Pruning techniques
  - Online knowledge [BH04] [YYK+06]
  - Offline knowledge [ST09] [HCL10a]
- Parallel Monte-Carlo game tree search [CJ08] [CWvdH08]

Case study:
- Computer Chinese chess [YCYH04]
- Computer Chinese dark chess [CSH10] if time allowed
Other games – if time allowed

- **Games with imperfect information and stochastic behaviors** [FBM98]
  - Backgammon
  - Bridge

- **Multi-player games** [Stu06]
  - Poker
  - Majon
Practical considerations (1/2)

- Transposition tables
  - Recording prior-search results to avoid researching
  - Design of a good hash function
    - Zobrist’s hash function \cite{Zob70}

- Open-game \cite{Hy99} \cite{Bu99} and endgame databases \cite{Th86} \cite{Th96} \cite{Wl06}
  - Off-line collecting of knowledge
  - Computation done in advance

- The graph-history interaction (GHI) problem \cite{Ca85} \cite{Bv98} \cite{Wh05}
  - The value of a position depends on the path leading to it.
    - Position value is dynamic and static.
Practical considerations (2/2)

- **Opponent model** [CM96]
  - How to take advantage of knowing the playing style of your opponent.

- **Timing and resource usage control** [Hy84] [HGN85] [MS93]
  - Using time wisely
    - Use too little time in the opening may be fatal.
    - Use too much time in opening may be fatal, too.
    - Knowledge from real tournament environments [vV09].
    - For Monte-Carlo type of search [HCL10b].

- **Hardware enhancements** [DL04]

- **Parallelization** [Bro96] [Man01]
Concluding remarks

- Search chance nodes
- How to put everything together
- How to test your implementation
Resources (1/5)

- **ICGA web site**
  - http://ticc.uvt.nl/icga/
  - Formally as ICCA (International Computer Chess Association)
    - *Between 1977 and 2001.*

- **International Computer Games Association**
  - *Since 2002.*

- **Host of Computer Olympiad**
  - *International competition of games played by computers*
  - Hold every year since 2000
  - 1989 at London, United Kingdom (1st)
  - 2004 at Ramat-Gan, Israel (9th)
  - 2005 at Taipei, Taiwan (10th)
  - 2011 at Tilburg, the Netherlands (16th)
  - 2013 at Yokohama, Japan (17th)
Resources (2/5)

- **TCGA web site**
  - Taiwan Computer Games Association
  - Since 2011.
  - http://tcga.ndhu.edu.tw
  - Annual conference and tournaments

- **TAAI game tournaments**
  - Taiwan AI Association
    - http://www.taaai.org.tw/TAAI/
  - Annual conference since 2001
  - Annual game tournament since 2009
Resources (3/5)

- **Proceedings of IJCAI**
  - International Joint Conference on Artificial Intelligence
  - Covers all areas of A.I.
  - Computer games occupy only a small session now
  - Since 1969, odd numbered of years

- **Proceedings of AAAI**
  - Association for the Advancement of A.I.
  - Covers all areas of A.I.
  - Computer games occupy only a small session now
  - Since 1980
Proceedings of the ACG conference

- Advances in Computer Games International Conference
- Every (if possible) odd numbered of year
  - 1999 at Paderborn Germany (9th)
  - 2003 at Graz, Austria (10th)
  - 2005 at Taipei, Taiwan (11th)
  - 2009 at Pamplona, Spain (12th)
  - 2011 at Tilburg, the Netherlands (13th)

Proceedings of the CG conference

- Computers and Games International Conference
- Since 1998, even numbered of years

Proceedings of IEEE CIG

- Computational Intelligence and Games International Conference
- Since 2005, every year.
- Video game, ...
Resources (5/5)

- **Artificial Intelligence**
  - Flagship journal
  - Since 1970

- **ICGA journal**
  - Quarterly publication since 1977

- **The A.I. magazine**
  - Journal for AAAI
  - Since 1980

- **IEEE transactions on Computational Intelligence and A.I. in Games**
  - A new IEEE journal
  - Quarterly publication since 2009
References


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